# Contribution of walking to school to individual and population moderate-vigorous intensity physical activity

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# Contribution of walking to school to individual and population moderate-vigorous intensity physical activity: systematic review and meta-analysis

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**Running Head**: MVPA during walking to school

## Abstract

**Purpose**. This study estimated the contribution of walking to/from school to objectively measured daily moderate-vigorous intensity physical activity (MVPA) in individuals and populations. **Methods.** MEDLINE, PsycINFO and SPORTDiscus were systematically searched up to February 2015. Two reviewers independently screened titles/abstracts/full-text articles, and assessed study quality. **Results.** Of 2430 records, 116 were eligible for full-text screening. Twelve studies met the inclusion criteria of reporting objectively obtained measures of MVPA (total and while walking to/from school) in children and adolescents. The weighted mean MVPA accumulated in walking to and from school was 17 minutes per day in primary school pupils (9 samples, n=3422) and 13 minutes per day in high school pupils (4 samples, n=2600). Pooled analysis suggested that walking to and from school contributed 23% and 36% of MVPA on schooldays in primary school age children and high school pupils, respectively. All included studies were of high methodological quality. **Conclusions.** Walking to and from school makes a meaningful contribution to individual schoolday MVPA for active commuters in western countries. Since schooldays represent only around half of all days, and prevalence of walking to school is low in many countries, the contribution of walking to school to population MVPA is probably low.

## Introduction

Recent reviews have suggested that active commuting (walking, cycling) to school has a number of health and non-health benefits, including potentially reduced adiposity, and environmental gains arising from reduced car use (15, 26,40,42). Active commuting to school is an important element of physical activity and health policy in many parts of the world. Active commuting to school is widely considered as an important contributor to the achievement of daily moderate-vigorous intensity physical activity (MVPA) recommendations (5,50), but there has been a marked decline in the prevalence of active commuting to school internationally (11,12,49).

A great deal of research and policy effort has focused on interventions to increase the prevalence of active commuting to school, with the implicit assumption that such interventions will produce a meaningful increase in population MVPA. Assessing the extent to which future research and policy should focus on active commuting to school depends on an improved –more quantitative-understanding of the contribution which it actually makes to MVPA. The MVPA accumulated during active commuting is usually seen by researchers and policymakers in terms of the individual child who is commuting actively, and with a focus on schooldays. A population perspective of the contribution of active commuting to school to MVPA would place less emphasis on individual active commuters and schooldays, by considering both the fact that not all days are schooldays (18), and the prevalence of active commuting, which is very low in many countries (49).

Recent reviews and original studies on the topic of active commuting to school have asked research questions about secular trends in, and prevalence of, active commuting

(11,12,31,41,42,49) ; the main determinants and correlates of active commuting (12,27,47); the efficacy of interventions to  promote active commuting (29), and the health effects of active commuting (8,15,24,26, 34,40,41).These reviews have generally made the implicit or explicit assumption that active commuting to school makes a meaningful contribution to individual and/or population MVPA. To date, no systematic review has asked a research question about the amount of MVPA which is actually being accumulated by children and adolescents in active commuting to school, and the extent to which MVPA accumulated during the active commute contributes to population MVPA. The primary aims of the present study were therefore to systematically review and critically appraise the evidence on the amount of MVPA being accumulated while walking to/ from school, and to examine the contribution of MVPA while walking to school to overall MVPA on schooldays in those individuals. The secondary aim was to consider the contribution of walking to and from school to population MVPA, by allowing for days on which children and adolescents do not attend school, and the prevalence of active commuting in the population (18).

## Methods

### Literature searching and study inclusion criteria

The literature search was conducted in February 2015 using the three most relevant electronic databases: MEDLINE; PsycINFO and SPORTDiscus. The search strategy was based on the following components: population (children and adolescents); exposure (active commuting to and from school via walking); and outcome (objectively measured MVPA). While we originally considered the inclusion of data from children and adolescents who cycled to/from school the focus of the present review was walking to/from school, because in all eligible studies the prevalence of cycling to school was negligible and it was possible to extract data only from those who walked to/from school. In any case, accelerometry as used in most previous studies is unsuitable for measurement of MVPA during cycling (46). Studies published from 2004 were eligible for inclusion so that any evidence would be generalizable given recent rapid secular trends in active commuting (49). The search strategy in MEDLINE is given in **Table 1,** and was adapted as required for the other two databases. Full literature search details are available from the corresponding author on request. Reference lists of eligible studies were also examined for potentially eligible studies.

To be eligible for inclusion in the review, papers had to: report information on school-age children and adolescents (4 – 19 years of age); use objective methods for measuring MVPA (heart rate monitoring; accelerometry; combined heart rate monitoring-accelerometry; direct observation); report MVPA while walking to/from school, with any accelerometry cut-point or other objective method, be original research, published in a peer reviewed journal; be observational in design, though intervention studies were considered for inclusion if pre-intervention data and/or control group data were given separately; be published in the English language. There is no ideal (or even consensus) definition of active commuting to and from school, and so studies were not excluded on the basis of how they defined or operationalised active commuting. In most studies active commuting was operationalised as the time periods before and after school (typically the 1 hour before school and 1 hour after school), and so these will include some MVPA spent in domains other than active commuting. In all eligible studies the data extracted for the present review was considered to represent the estimated MVPA accumulated during the walk to and from school (and the MVPA on schooldays) among those who regularly walked to/from school. There is also no certainty (or even consensus) over which accelerometer data reduction decisions are ideal for minimising biases in MVPA estimates (9,13,17,21,37), and so studies were not excluded on the basis of the data reduction decisions they made.

Two authors independently considered the titles/abstracts of all papers identified by the search, referring to a third author for discussion and mediation where required. Two authors also examined the papers identified for full-text screening, and referred to a third author where necessary for discussion/mediation.

**Data extraction**

Three authors examined every eligible study and used a standard data extraction form in order to populate the evidence tables. The extracted items were: first author, publication year, country, objective measurement type, cut point for MVPA, sample size, mean age, summary MVPA data (minutes/day) walking to and from school and daily MVPA during schooldays for those who walked to and from school. Eligible studies included only participants who walked to school regularly and/or provided data for such individuals-for the present study data were extracted only from children and adolescent study participants who regularly walked to/from school.

**Data analysis and synthesis**

The eligible studies fell logically into two categories: studies of primary school pupils (elementary and middle school); studies of high school pupils, and so data were synthesised for these two age groups separately.

**Contribution of active commuting to *individual* MVPA for those who walk to school**

In some studies the MVPA content of commuting time was expressed as a percentage, and so absolute MVPA (minutes) was recalculated based on data on the percentage of time spent in MVPA and commuting time provided by each eligible study. For each individual study the proportional contribution of walking to and from school to total daily MVPA was calculated. An overall pooled estimate was calculated for primary school pupils and high school pupils by averaging the proportional contributions from each study. A weighting factor based on study sample size was used to weight proportional contributions in the pooled estimate.

**Contribution of walking to/from school to *population* MVPA, allowing for non-school days and prevalence of active commuting**

Since children and adolescents who walk to/from school can only do so on school days, and since not all children and adolescents walk to/from school, the contribution which walking to school makes to the overall population MVPA cannot be determined by considering active commuters and schooldays alone (18). In order to estimate the contribution of walking to/from school to *population* total MVPA, data on the proportion of days per year when children and adolescents attend school were used, along with data on the population prevalence of walking to school. Data on the number of schooldays attended per year vary both within-nations and between-nations. For the economically developed nations from which eligible studies were found in the present review, around half of all days per year are school days (33). To estimate the contribution of walking to/from school MVPA to total population MVPA, the schoolday commuting data can therefore be reduced by around half for those in the population who walk to/from school (18).

The contribution which walking to and from school makes to population MVPA will also depend on the population prevalence of active commuting-for children who do not walk to/from school the contribution which this behavior makes is negligible. The impact of the prevalence of walking to/from school on population MVPA was illustrated with two examples, taken from nations with studies eligible in the review and of interest because of the contrast they provide in the prevalence of walking to/from school: Scotland, where current prevalence of regular walking to school is around 50% (36); the USA, where prevalence of walking to school in children is <15% (11).

**Assessment of quality of the eligible studies**

Studies identified as eligible were assessed independently for quality by three authors, resolving any disagreements by discussion. The Tooth et al (48) tool for assessing the quality of observational studies was considered initially-it consists of over 30 items, and some items of particular importance to the quality of accelerometry studies are not included. The Tooth et al tool has been used previously, with substantial modification, in recent systematic reviews of physical activity studies with an 11-item

(19), or 8-item (45) checklist. In the present study the Tooth et al tool (48) was modified for use as a 15-item checklist, scored out of 6, as shown in **Table 2**. Each eligible study therefore received a score out of 6, with higher scores reflecting higher study quality.

## Results

### Study selection and characteristics of eligible studies

The study flow diagram is provided in **Figure 1**. Of 2430 records identified in the initial review of the three databases, 116 were identified for full text screening. Of these, 12 records were eligible for inclusion, reporting on 13 samples. Reasons for exclusion are reported in Figure 1.

All studies used the ActiGraph, though with a variety of different models as well as different approaches to data collection and reduction.

Nine samples involved primary school pupils, with a total sample size of 3422 children, in Denmark (1 study), England (4 studies), Scotland (1 study), and USA (3 studies). Study characteristics are summarized in **Table 3**. Four eligible samples involved high school pupils (**Table 4**), with a total sample size of 2600 adolescents, in three nations: Denmark (1 study); England (1 study); USA (2 studies).

### Results on walking to and from school in primary school pupils

The mean daily MVPA accumulated during the walk to and from school in these studies ranged from a low of 4 minutes/day in one study to 24 minutes/day in another

(**Table 3**). The weighted mean MVPA across the nine studies was 17 minutes per school day.

**Figure 2A** displays the proportional contribution of walking to and from school to total daily MVPA for each study. For those children who walked regularly to/from school, pooled analysis showed that the commute represented 23% of daily MVPA on schooldays.

**Results on walking to and from school in high school pupils**

The mean daily MVPA accumulated while walking to and from school ranged from a low of 9 minutes/day in one study to a high of 18 minutes/day in another (Table 4). Weighted mean MVPA in walking to and from school across the four studies was 13 minutes per day.

Proportion of walking to and from school to total daily MVPA for individual studies is summarized in **Figure 2B**. For those adolescents who walked to and from school regularly, pooled analysis showed that the contribution of the commute represented 36% of total daily MVPA on schooldays.

**Study quality assessment**

On quality assessment (Tables 2 and 3), all eligible studies scored at least 5/6.

## Discussion

**Main findings and implications**

The present study suggests that walking to and from school contributes about one quarter of *individual* total daily MVPA *on schooldays* for active commuters to primary school (contributing up to around a third of the recommended MVPA of 60 minutes/day on schooldays), and around one-third of total *school day* MVPA for active commuters to high school (contributing up to around a fifth of the recommended MVPA of 60 minutes/day on schooldays) in western countries. These findings illustrate the importance of active commuting to MVPA, for those individuals who commute actively, on schooldays.

For an understanding of the importance of active commuting to *population* MVPA the number of school days actually attended per year matters (18), as does active commuting prevalence. As an example, the only eligible study from Scotland (29) reported that primary school age children who walked to and from school accumulated around 16 minutes MVPA per school day while doing so, the equivalent of around 8 minutes MVPA per day when averaged over a whole year for individuals who commute actively. Since the population prevalence of regular walking to school in Scottish primary school children is currently around 50% (36), this means that the 8 minutes/day MVPA contribution to overall population MVPA (ie when those who do not walk to and from school are included) is reduced further.

In the USA, with a prevalence of walking to and from school of around 13% in 5-11 year olds (11), and mean MVPA during walking to school of around 4-14 minutes per school day (Tables 3 and 4), the current contribution of walking to and from school to *population* MVPA will be very low. In accelerometry studies of nationally representative samples of US children, mean daily MVPA estimates vary from a low of 75-95 minutes (3, 50), to a high of around 180 minutes (32). If these estimates are accurate, the present study suggests that nearly all population MVPA must be accumulated in domains other than active commuting to school (at home; in active and outdoor play; in school based physical activity-recess and physical education; in organized sport).

Walking to/from school may be associated with higher overall physical activity and may provide health and non-health benefits (15,40,43), but the present study suggests that it makes only a small contribution to *population* MVPA , probably a combination of low prevalence of active commuting to school, limited MVPA during the commute, short commuting distances (18, 22, 27,35,42), and the fact that so many days are not schooldays (12,18). If walking to school is going to make a much greater contribution to population MVPA in future, the prevalence, duration, and MVPA content of walking to school must all be increased substantially. A discussion of policy and strategy options and arguments for improving surveillance of active commuting to school, and for increasing the prevalence and MVPA content of active commuting to school, would go beyond the scope of the present study, but these issues are dealt with elsewhere (31,42,49, 51,52). Researchers and policymakers should also consider whether focusing on domains of physical activity other than active commuting to school might be more effective in the promotion of population MVPA (18).

**Comparisons with other studies**

Since previous systematic reviews on active commuting to school have asked research questions distinct from the present study, there are no directly comparable reviews.

Janssen (18) recently examined the relative public health gain in Canada, of targeting different physical activity domains (active commuting vs. physical education, active play, school recess, and organised sport). He concluded that successful promotion of active commuting to school might make only a relatively small contribution, in part because school days represent only around half of all days, and in part because walks to school were typically short.

**Review and evidence strengths and weaknesses**

The present study represents a high-level of evidence. The study had an *a priori* protocol and followed PRISMA guidelines in conduct and reporting (30). The evidence considered by the present review had a number of strengths too. In particular, eligible studies were all rated as being of high or very high quality. The studies included were in some cases based in large, nationally representative, surveys or cohorts, a strength in terms of generalizability.

The present study also had a number of weaknesses. First, studies eligible for inclusion had to be published in peer reviewed journals in English language, and this may have excluded relevant evidence. Literature searching was restricted by starting the search for papers published from 2004: this may be seen as a weakness, but was intended as a strength, to focus the review on more recent, and more generalizable evidence given rapid secular declines in active commuting to school. The present study used a 15-item quality assessment measure, but collapsing this to 6 items for scoring purposes might have reduced the ability to discriminate between studies on the grounds of quality.

Various limitations probably led to overestimates of the estimated MVPA content of the walk to/from school. In most eligible studies the walk to and from school was operationalized as specified periods before and after school (typically in the hour before school and the hour after school), so MVPA accumulated will be greater than the MVPA during the walk *per se*, by including some MVPA in domains other than active commuting (e.g. play, sport). Walking to and from school might provide opportunities for active play which would not be available when commuting passively, though these opportunities may not always be realised (44). Removal of the accelerometer by study participants before the end of the day may have biased eligible studies towards an overestimate of the contribution of the commute to schoolday MVPA in some cases. The use of low accelerometer cutpoints may also have inflated the absolute amount of MVPA during the commute.

The present study did not consider light intensity physical activity during walking to and from school, but there is an emerging body of evidence that light intensity physical activity may have a number of health benefits for children and adolescents (4,14,23,25).It is unlikely that all walking to school is MVPA, and indeed several studies of the energy cost of walking in children and adults give mean values for walking of less than three times resting energy expenditure, and so categorise walking as a light intensity activity (1,2).

One major gap in the eligible evidence reviewed by the present study was the absence of data from low-middle income and non-western countries. The decision to restrict the search to studies in the English language may have contributed to this. Developing countries around the world are undergoing a ‘physical activity transition ‘(20,31) and recent international surveillance of active commuting to school (49) has suggested that the secular decline in active commuting to school seen in high-income countries may also be occurring in low-middle income countries. In many countries a minority of children will be commuting actively to school, and prevalence of active commuting will be declining (15,41,49). In a recent study of children in rural South Africa, walking long distances to school was the norm, but the speed of walking was low and so the MVPA accumulated during the walk to/from school was limited (10). It is not clear whether these findings from South Africa apply to other low and middle-income countries.

## Conclusions

The present study suggests that walking to and from school may make a meaningful contribution to individual schoolday MVPA in western countries for those individuals who commute actively. If walking to school is going to make a more substantial contribution to *population* MVPA, then the prevalence will have to be increased markedly. The extent to which walking to school is contributing to individual or population MVPA among children and adolescents in low and middle-income countries is less clear.

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**Table 1 Search Strategy in MEDLINE**

| |
|---|
| exp child/ |
| exp adolescent/ |
| child*.tw. |
| adolesc*.tw. |
| (boy* or girl*).tw. |
| teen*.tw. |
| youth*.tw. |
| (pupil* or student* or schoolchild*).tw. |
| (young adj2 (person* or people)).tw. |
| p?diatr*.tw. |
| school*.tw. |
| 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 |
| exp Walking/ or exp Bicycling/ |
| *Travel/ |

(active adj2 (commut* or transport* or travel* or lifestyle* or life-style* or living)).tw.

(walk* or cycl*).tw.

13 or 14 or 15 or 16

exp Motor Activity/

exp Exercise/

*physical endurance/ or exp physical fitness/

*Sports/

21 or 18 or 19 or 20

(physical* adj2 activ*).tw.

exercis*.tw.

"physical fitness".tw.

"physical endurance".tw.

(physical activity adj2 (level* or intensit* or energy expenditure)).tw.

"MVPA".tw.

moderate-to-vigorous.tw.

"moderate to vigorous".tw.

22 or 23 or 24 or 25 or 26 or 27 or 28 or 29 or 30

objectiv* measur*.tw.

exp actigraphy/ or *monitoring, ambulatory/

exp Accelerometry/

32 or 33 or 34

("GPS" or global positioning system or "GIS" or global information

system).tw.

acceleromet*.tw.

(activpal or activgraph or activity monitor*).tw.

heart rate monitor*.tw.

35 or 36 or 37 or 38 or 39

12 and 17 and 31 and 40

limit 41 to english language

limit 42 to yr="2004 -Current"

**TABLE 2 Study Quality Assessment Criteria**

| Criterion | Definition | Mark Allocation |
|---|---|---|
| Sample recruitment | Sample: How were they recruited e.g. poster<br>Time: When was the study conducted<br>Place: Where did the recruitment take place | 1 point for listing 3 criteria |
| Sample description (n, age, gender) | Number of participants recruited<br>Mean age of participants<br>% Gender male and female | 1 point for listing all 3 criteria |
| Attrition | Number of participants recruited and the number actually measured | 1 point for listing both criteria |
| Data collection and reduction | Type of device; epoch; no of days of active commuting specified as minimum; duration of monitoring time; monitor placement; data reduction decisions | 1 point for listing 3 criteria |
| MVPA definition given | MVPA defined and accelerometry cut-off or other method given | 1 point for listing both criteria |
| Results | Adequate description of numbers actually analysed, with summary MVPA data | 1 point for listing both criteria |

**TABLE 3 Contribution of Walking to and from School to Daily MVPA in Primary School Studies**

| Study, Year, Setting | Accelerometer, MVPA cut-off Point | Sample Size; Mean age (SD) | Total mean schoolday MVPA [minutes/day] | Mean MVPA Walking to/from school [minutes/day] | Quality Rating |
|---|---|---|---|---|---|
| McMinn et al 2012, Scotland (29) | ActiGraph GT1M, Freedson cutpoint[d] | 166; 8.6y (0.5) | 90 (SD 27) | 16 (SD 8) | 5 |
| Owen et al 2012, England (34) | ActiGraph GT1M, ≥2000 cpm | 1393; 9.9y (0.4) | 74 (95% CI 71-76) | 22 (95% CI 21-23) | 6 |
| Panter et al 2011, England (35) | ActiGraph GT1M, ≥2000 cpm | 723; 10.2y (0.3) | 74 (SD 23) | 15 (SD 7) | 6 |
| Lee and Li 2014, USA (27 ) | ActiGraph GT1M and GT3X, Freedson cutpoint [d] | 109; 9.5y(not given) | 63 (SD 11) | 7 (SD 10) | 5 |
| Cooper et al 2005, Denmark (8) | ActiGraph 7164, cut-point unclear | 328; 11y (0.4) | 193 (SD 59) | 7 (SD not given) | 5 |
| Cooper et al 2012[a], England (6) | ActiGraph GT1M, ≥2295 cpm | 500; 11y (0.4) | 62 (SD 22) | 14 (SD not given) | 6 |
| Cooper et al 2010, England (7) | ActiGraph GT1M, ≥3200 cpm | 70; 11y (0.3) | 43 (SD 18) | 11[b] (SD 5) | 6 |

| | | | | | |
|---|---|---|---|---|---|
| Sirard et al 2005, USA (41) | ActiGraph, model not given, ≥1017 cmp | 21; 10y(0.6) | 102 (SD not given) | 24 (SD not given) | 6 |
| Saksvig et al 2007[c], USA (38) | ActiGraph 7164, ≥1500 counts per 30 seconds | 112; 6th grade | 29 (SD 2) | 11 (SD 1) | 6 |

[a] Primary school age sample from Cooper et al 2012 (6). [b]Paper provided MVPA during route to school only, so has been doubled. [c] Study of girls only. [d] Freedson MVPA cutpoint (16) equivalent to 906cpm and 1018cpm for 9 and 10y olds respectively, using the following equation

METS = 2.757 + (0.0015 x counts/min) – (0.08957 x age (yr)) – (0.000038 x counts/min x age (yr))

In all cases daily MVPA data refer to schooldays only among children who walked to school regularly. MVPA: moderate-to-vigorous physical activity, cpm: counts per minute

**TABLE 4 Contribution of Walking to and From School to Daily MVPA in High School Studies**

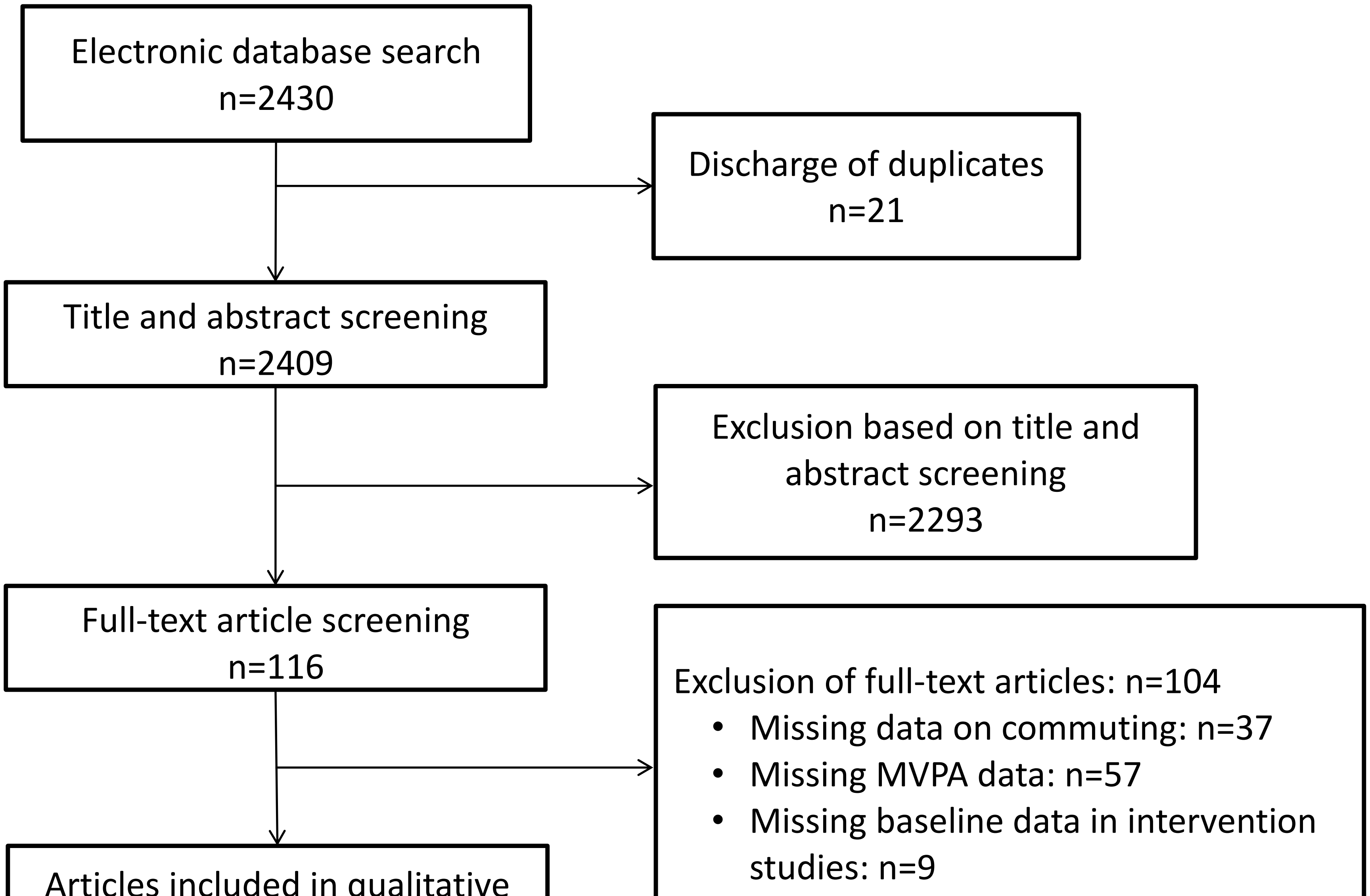
| **Study, Year, Setting** | **Method and Cut Point** | **Sample Size; Mean (SD) age** | **Mean total schoolday MVPA [minutes/day]** | **Mean MVPA Walking to/from school [minutes/day]** | **Quality Rating** |
|---|---|---|---|---|---|
| Mendoza et al 2011, USA (28) | ActiGraph 7164, Freedson cutpoint [a] | 789; 14.4y (SE 0.1) | 30 (SE 2) | 9 (SE 1) | 6 |
| Klinker et al 2014, Denmark (22) | ActiGraph GT3X,$\geq$ 2296 cpm | 367; 13.2y (0.2) | Median 64 (IQR 42-97) | Median 10 (IQR 5-16) | 5 |
| Cooper et al 2012[b], England (6) | ActiGraph GT1M, > 2295 cpm | 500; 12y (0.4) | 63 (SD 23) | 18 (SD not given) | 6 |
| Saksvig et al 2012, USA (39) | ActiGraph 7164, $\geq$ 3000 cpm | 944; 14y(SD not given) | 26 (SD 2) | 14 (SD 1) | 6 |

[a]Freedson MVPA cut-point (16) equivalent to 1546cpm in 14y olds , using the following equation

METS = 2.757 + (0.0015 x counts/min) – (0.08957 x age (yr)) – (0.000038 x counts/min x age (yr))

[b]Secondary school data from Cooper et al 2012 (6).

Daily MVPA estimates are schoolday MVPA in study participants who walked to school regularly. MVPA: moderate-to-vigorous physical activity, cpm: counts per minutes


Electronic database search
n=2430
Discharge of duplicates
n=21
Title and abstract screening
n=2409
Exclusion based on title and abstract screening
n=2293
Full-text article screening
n=116
Exclusion of full-text articles: n=104
• Missing data on commuting: n=37
• Missing MVPA data: n=57
• Missing baseline data in intervention studies: n=9
Articles included in qualitative

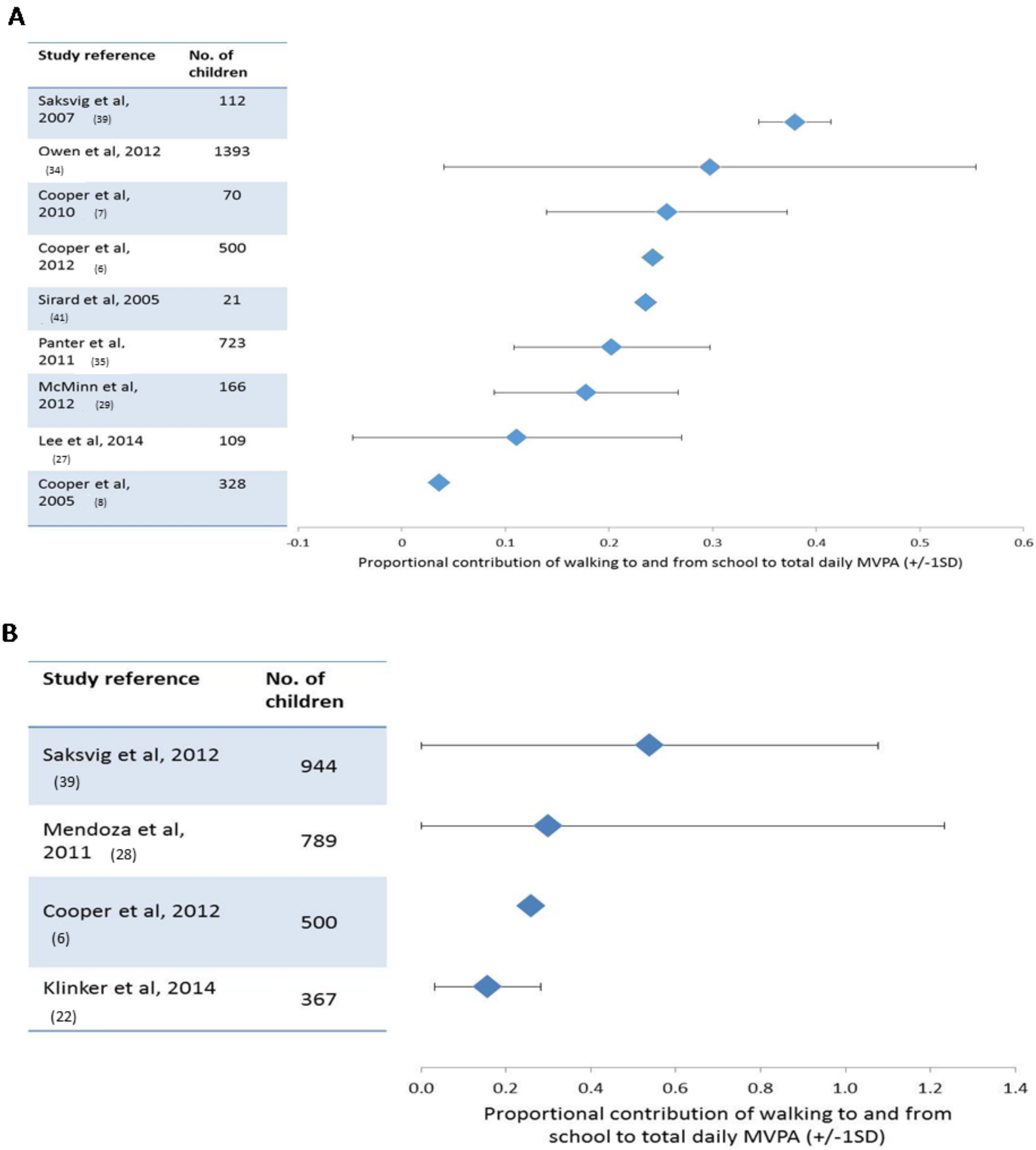



**Figure 2** Proportional contribution (mean, SD) of daily walking to and from school to total moderate-to-vigorous physical activity (MVPA) on schooldays. A: Primary school pupils, B: High school pupils.